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Determination of Water Quality Index for Various Sources of Drinking Water in Tando Allahyar City

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***Abstract*— Water is vital to human existence, and recently, the demand for bottled water has increased for drinking purposes. However, people still use tap water and groundwater for different purposes due to their financial constraints. The examination of Tando Allahyar city's water quality is necessary due to the issue of people's access to clean drinking water. This research has determined the water quality of these three sources of drinking water, viz. Bottled water, tap water, and groundwater at Tando Allahyar were evaluated using the Water Quality Index (WQI) criteria. This research will increase public awareness. WQI was determined using various water quality parameters (physical, chemical, and biological), including pH, total dissolved solids, electrical conductivity, hardness, dissolved oxygen, total coliforms, and chloride. This research computes the WQI for all three water sources used in three selected areas of Tando Allahyar City. This research compares the WQI of various drinking water sources and proposes possible solutions to ensure safe, affordable drinking water. Three locations in Tando Allahyar provided tap and groundwater samples, which were gathered and evaluated in the lab. These locations include Prem Nagar, Qila Area, and Mujahid Colony, and the most commonly used Bottled Waters were collected in the same areas of the city. The WQI of tap water at three selected locations was within the good-quality range. The WQI of groundwater at two selected locations was in the poor-quality range; however, one location was in the good-quality range, though still on the borderline. The WQI of all seven bottled waters was in the excellent range. The study contributes to clean drinking water and raises awareness of the health risks posed by low-quality water.**

***Index Terms*— Water Quality Index, Tap Water, Groundwater, Bottled Water, Public Health**

I. INTRODUCTION

A fundamental aspect of public well-being and a basic human right is access to clean drinking water. Nevertheless, in numerous developing nations, the absence of access to safe drinking water has been positioned as one of the major sources of disability-adjusted life years and death. The World Health Organization (WHO) states that at the end of the 1990s, about 40% of the deaths in such countries were found to be “water-related”, and today, millions are still suffering from water-borne diseases every year [1]. Water quality degradation is a worldwide issue that contaminates drinking water with chemical, microbial, and physical agents through industrial discharges, agricultural non-point sources, and municipal sewage.

Deteriorating water quality led to one of the key responses: increased reliance on bottled water. Global consumption of bottled water has doubled over the last 30 years, accounting for more than 12% of beverage consumption [2]. Findings from the Pakistan Council of Research in Water Resources (PCRWR) 's recent monitoring indicate that most brands are not microbiologically or chemically safe, with affordability and quality as two areas of concern [3].

Even though there have been many investigations carried out to analyze drinking water quality in various parts of Pakistan, very few investigations exist comparing the Water Quality Index (WQI) of bottled water, groundwater, and tap water in one particular urban area. The current investigation is a step toward filling the research gap in the field by analysing the three aforementioned types of drinking water in the city of Tando Allahyar using the WQI technique.

Treatment capacity, ageing infrastructure, and improper disinfection practices have resulted in about 70% of drinking water sources in Pakistan failing to meet WHO standards due to widespread bacteriological and arsenic contamination [4]. The crisis is also reflected in the composition of the water available to residents of Tando Allahyar: municipal tap water, water from private bore wells, and bottled water, each limited in different ways: tap water is prone to microbial contamination, groundwater is typically saline or, not uncommonly, chemically contaminated, and bottled water is expensive and has a vacuum of inconsistency in safety. Hence, using a multi-parameter approach that includes parameters such as pH, TDS, hardness, chlorides, dissolved oxygen, conductivity, and microbiological content, the current work employs the Water Quality Index (WQI) to evaluate and compare the quality of all three sources.

II. LITERATURE REVIEW

The Water Quality Index (WQI) is one of the most popular methods for combining several physicochemical and microbiological parameters into an integrated indicator of water

quality. Drinking water safety has been a significant focus of environmental and public health studies for decades. Worldwide, WQI has the potential to be used for surface, ground, and bottled water to show environmental degradation and human health risk, which is one of the most important issues in Pakistan because Pakistan lacks centralized treatment facilities, and groundwater is the primary source of supply.

Numerous studies have highlighted Pakistan's heterogeneous groundwater quality. The authors in [5, 6] reported that Tharparkar contained a large proportion of samples exceeding acceptable TDS levels for drinking purposes. Seawater intrusion was documented in coastal Thatta by [2], with over half of the samples exceeding WHO standards. In Model Colony, Karachi, [7] observed that hardness and turbidity were within acceptable limits, but faecal coliforms and heavy metals exceeded safe limits, and industrial effluent discharges and poor sanitary conditions were significant contributors to the contamination of the source water. The arsenic contamination makes it worse. The authors in [8] found 28 percent of Nankana groundwater samples above WHO arsenic thresholds. These findings indicate that not only salinity but also trace metal contamination are important health risks in rural and semi-urban Pakistan. Previous research had warned about chemical leaching if plastic bottles are left in hot environments. The authors of [1] found that although bottled water was safer than tap water in Abbottabad, Pakistan, it still posed a microbiological risk. In Lahore, both bottled and tap water regularly failed to meet the microbial safety standard.

Similar concerns have been raised in studies conducted elsewhere in South Asia and the Middle East. The authors in [9] observed variation between brands in bottled varieties. For example, [10] states that customers' opinions about the quality of the water influence the distinguishing features of bottled water consumers, and those with lower incomes cannot afford bottled water. Since they can only afford to drink tap water, which is also the case in Pakistan, where bottled water is heavily consumed by middle and upper-income groups.

III. MATERIALS AND METHODS

The present study was conducted in Tando Allahyar city, Sindh province, Pakistan (25°27′N, 68°43′E), where the primary sources of drinking water are bottled water, groundwater, and municipal tap water. They were evaluated for suitability for human consumption using the Water Quality Index (WQI). Three representative localities in the city were targeted for water sampling: Mujahid Colony, Qila Area, and Prem Nagar. Household-based tap water and groundwater samples were collected in the summer of 2024, and bottled water was purchased from the same localities, either from local retailers or supermarkets, for comparison. To represent the common bottled water in the area, popular commercial brands such as Nestlé, Ocean Mineral Water, and Milat were included. Three samples from each source were gathered, placed in containers that had been previously cleaned and labelled with the location and source, and taken to the lab under standard conditions for analysis. Within 24 hours, every parameter was examined. So as not to compromise the sample's integrity. For each source, three independent samples were collected, and the average value was used for further analysis.

Water sample analyses were carried out for seven key physicochemical and microbiological parameters (TDS, hardness, pH, chloride, EC, DO, and total coliforms) using standard laboratory methods in accordance with the guidelines provided by WHO (2022) and APHA (2017). The Water Quality Index (WQI) was determined (Table I) based on considered weights assigned to each parameter and integrated results in five quality levels: excellent, good, moderate, poor, and unsuitable. Instrument calibrations were performed before any tests, and each parameter was analyzed in triplicate to maintain reliability; the mean values were used for WQI calculation.

WQI CALCULATION:

To compute the WQI the following four steps have been followed

Step 1: Each parameter has been given a weightage and then the relative weightage w_i for each parameter has been determined by using an equation

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

W_i= Relative weightage

w_i= Weightage of each parameter.

Step 2: Quality rating has been determined by using the following equation.

$$Q_{i=\frac{C_i}{S_i}\times 100} \qquad (2)$$

Where

Q_i= quality rating

C_i= concentration of each parameter in each water sample.

S_i = permissible limit value of each parameter

Step 4: The following formula has been used to calculate the water quality index.

$$WQI = \sum_{i=1}^{n} SI \qquad (3)$$

IV. RESULTS

This chapter presents the findings from analyses of various drinking water sources in the study area.

A. Tap Water Quality

The Water Quality Index (WQI) Table II indicates that the status of the tap water in the three locations selected in this study, Prem Nagar, Mujahid Colony, and Qila Area at Tando Allahyar city, has WQI scores of 51.39, 52.89, and 55.67, respectively. These scores fall under the ‘Good’ category (Fig. 1).

TABLE I. RELATIVE WEIGHTS OF PARAMETERS FOR WQI

S. No.	Parameters	WHO Standard	Weight (w_i)	R Weight (W_i)
1	TDS	6000mg/L	5	0.18518
2	Hardness	500mg/L	3	0.11111
3	pH	6.5 – 8.5	3	0.11111
4	Chloride	250mg/L	3	0.11111
5	EC	3dS/m	3	0.11111
6	DO	6-8.5 mg/L	5	0.18518
7	Total Coliforms	0 CFU/100ml	5	0.18518

TABLE II. WATER QUALITY INDEX RANGE AND WATER QUALITY

Class	WQI Range	Water Quality
1	<50	Excellent
2	50-100	Good
3	100-200	Poor
4	200-300	Very Poor
5	>300	Unsuitable

TABLE III. STATUS OF WQI OF TAP WATER AT SELECTED LOCATIONS

Location	WQI	Status
Prem Nagar	51.39	Good
Mujahid Colony	52.90	Good
Qila Area	55.68	Good

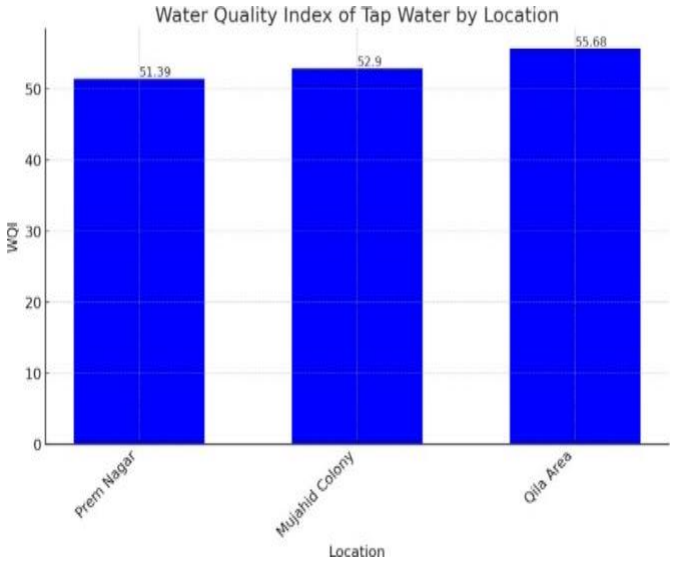

Fig.1. Chart of WQI of Tap Water at selected locations

B. Ground Water WQI:

The Water Quality Index (WQI) Table III indicates the status of the ground water in the three locations selected in this study, Prem Nagar, Mujahid Colony, and Qila Area at Tando Allahyar city. Prem Nagar has a WQI score of 99.7025 and falls under the "Good" category, while Mujahid Colony and Qila Area have WQI scores of 102.6222 and 103.0702, respectively. These scores fall under the 'poor' category (Fig. 2).

TABLE IV. STATUS OF WQI OF GROUND WATER AT SELECTED AREAS

Location	WQI	Status
Prem Nagar	99.7025	Good
Mujahid Colony	102.6222	Poor
Qila Area	103.0702	Poor

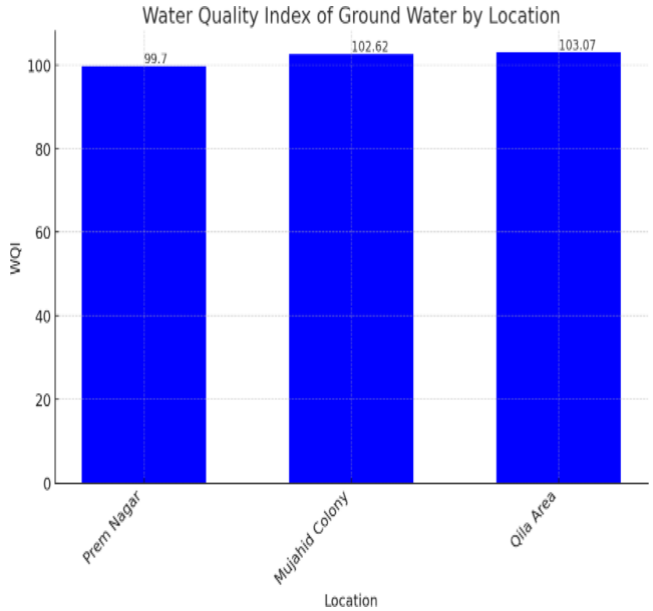

Fig. 2. Water Quality Index of Ground Water at Selected Locations

C. Bottled Water WQI:

The Water Quality Index (WQI) value indicates the status of bottled water in the city of Tando Allahyar Table IV. Nestle Pure Life has a WQI of 34.8782. While other bottled waters from Oxyrich to Water G have a WQI of 37.6641 to 41.49. All bottled water scores fall under the "excellent" category (Fig. 3).

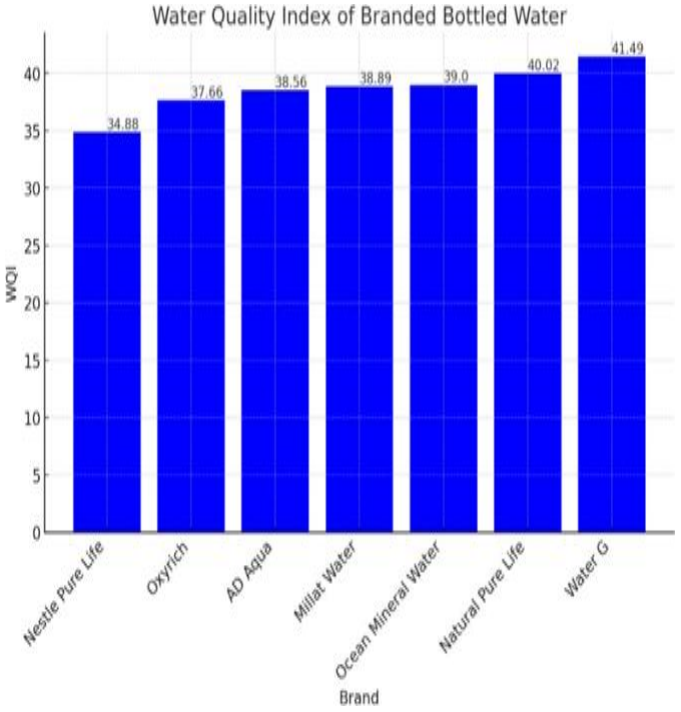

Fig.3. Water Quality Index of Bottled Water

D. Comparative Assessment of Drinking Water Sources

The safest source in Tando Allahyar was bottled water, which always fell in the "excellent" category, whereas tap water remained "good" but closer to the cutoff point for deterioration (Table V). In contrast, groundwater was of low quality at two of the three sites, suggesting a significant risk of contamination. These results emphasize an urgent requirement for regulated water management to provide better access to clean drinking water (Table VI).

TABLE V. STATUS OF WQI OF BOTTLED WATER AT TANDO ALLAHYAR CITY

S. No.	Name of Company	WQI	Status
1	Nestle Pure Life	34.8782	Excellent
2	Oxyrich	37.6641	Excellent
3	AD Aqua	38.561	Excellent
4	Milat Water	38.8921	Excellent
5	Ocean Mineral Water	38.9992	Excellent
6	Natural Pure Life	40.0247	Excellent

TABLE VI. COMPARISON OF WQI OF VARIOUS SOURCES OF DRINKING WATER

Location	Source of Water						
	Tap Water		Ground Water		Bottled Water		
	WQI	Status	WQI	Status	Company	WQI	Status
Prem Nagar	51.39	Good	99.7	Good	Nestle Pure Life	34.88	Excellent
					Oxyrich	37.66	Excellent
Qila Area	52.9	Good	103.07	Poor	AD Aqua	38.56	Excellent
					Milat Water	38.89	Excellent
Mujahid Colony	55.68	Good	102.62	Poor	Ocean Mineral Water	39.0	Excellent
					Natural Pure Life	40.02	Excellent
					Water G	41.49	Excellent

V. DISCUSSION

The tap water quality index for Prem Nagar, Mujahid Colony, and Qila Area in Tando Allahyar showed a "good" rating, ranging from 51.39 to 55.67. This rating is good, but with effort, it can be improved to an excellent rating, as the water quality index may be affected by increased water pollutants. Similar results were obtained in Lahore, as mentioned in [11], indicating a low water quality index rating in tap water due to old pipelines and industrial waste, posing a threat to water quality in Tando Allahyar as well. This study indicates that tap water is of good quality, but with continuous monitoring, its quality can be improved; therefore, it needs to be strictly monitored.

Groundwater quality was found to vary, with Prem Nagar rated as "good" (WQI 99.70), while Mujahid Colony (WQI 102.62) and Qila Area (WQI 103.07) were rated as "poor." This is in line with the results of broader studies in the Sindh region, which showed that groundwater quality was poor due to exceedance of EC, TDS, chloride, hardness, and heavy metals [1]. Though the Arsenic level was excluded from the present study because it required more time and higher costs, and research was conducted on those parameters that are uniform for all samples, historical surveys showed that arsenic levels in groundwater in the Tando Allahyar region exceed WHO and national limits, with nearly half of the samples exceeding 100

ppb, thus highlighting the vulnerability of groundwater aquifers to such contaminants. Recent studies in the Sanghar District also showed WQI values ranging from "excellent" to "poor," again reflecting the spatial variability of groundwater [12].

On the contrary, the values of bottled water consistently fell within the "excellent" WQI range (34-41). Among the bottled water brands, Nestle had the lowest values. This is also consistent with the national assessment [13], as commercial brands were found to meet WHO standards; however, periodic monitoring by PCRWR also revealed instances of non-compliance at times. Bottled water, when properly treated, has very low TDS, suitable chloride content, and no coliforms; therefore, it is the safest choice from a short-term perspective. However, this cannot be considered a long-term solution due to affordability issues and occasional non-compliance with the standards.

Since the groundwater WQI is poor, the water is affected by high levels of dissolved solids and microbial contaminants, making it unfit for human consumption without proper treatment. On the other hand, the good WQI of tap water indicates that the municipal water is treated, but some degradation occurs during transportation through the supply chain. The excellent WQI of the bottled water indicates that commercial treatment is efficient and that the water meets drinking water requirements.

Nevertheless, this research had some limitations. Firstly, the number of samples collected from selected locations of Tando Allahyar city was limited. Secondly, this research was based on 7 parameters, namely pH, TDS, EC, chloride, hardness, DO, and total coliforms. The selected parameters do not include all parameters of the water quality index. Thirdly, this research did not consider seasonal variations in water. The results of this research do not show how water quality could change during different months or seasons. Fourthly, this research was based on a limited set of microbiological parameters, with only one parameter considered.

Taking these constraints into account, future research efforts should focus on implementing comprehensive seasonal monitoring to assess variability in the water quality index under various weather conditions. In addition, using more variables in the analysis, especially heavy metals and microbiology tests, will contribute to a more accurate assessment of health risks. Lastly, implementing a system of water quality monitoring over time would provide useful information for sustainable water management.

The findings of this research align with recent international studies, which indicate that bottled water quality is better than that of groundwater, whereas tap water quality varies with the effectiveness of treatment and distribution processes. The same trend was observed in developing nations, where groundwater quality is usually influenced by both geological features and human activities. From a practical point of view, these results underscore the importance of groundwater quality monitoring, treatment of groundwater sources, and maintenance of municipal water systems.

VI. Conclusion

Significant differences in drinking water quality in Tando Allahyar have been identified in this study, with bottled water identified as the safest, tap water as good, and groundwater as unsafe. Even though bottled water provides a solution in the meantime, it is still expensive and unsustainable for consumers in the long term. The study has highlighted the need for urgent attention to improvements in municipal infrastructure, such as pipe replacements and increased monitoring across all sources of drinking water, and for implementing solutions to improve groundwater protection, such as recharge wells.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest to report regarding the present study.

AUTHOR CONTRIBUTIONS

Conceptualization, D.K. and P.K.; methodology, D.K.; software, D.K. and P.K.; validation, D.K.; writing—original draft preparation, D.K.; writing—review and editing, P.K.

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DATA AVAILABILITY STATEMENT

Data is available on reasonable request.

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